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A PORTABLE PENETROMETER FOR MEASURING LEAF TOUGHNESS IN INSECT HERBIVORY STUDIES

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Abstract.—An inexpensive, portable penetrometer and tongs for measuring leaf toughness are described. These allow measurements to be made while leaves remain attached to the plant.

Key Words: Penetrometer, tongs, leaf toughness, insect herbivores

Leaf toughness has been related to feeding preferences of insect herbivores. Several penetrometers for measuring leaf toughness have been described (Williams 1954, Cherrett 1968, Feeny 1970, Beckwith and Helmers 1976, Wright and Fuller 1984), based on measuring the weight or pressure required to force needles or probes through leaves. However, they can only be used when held upright or horizontal and are difficult or impossible to use without removing leaves from plants. A simple leaf penetrometer was described by King (1988), but it required more than one operator for use in the field. Designs for portable penetrometers used to measure fruit firmness were discussed by Abbott et al. (1976) while more sophisticated, non-portable penetrometers gave greater accuracy for measuring fruit firmness (Blanpied et al. 1978, Lidster et al. 1978, Abbott et al. 1984). These penetrometers also measured deformation of the fruit by compression (Bourne 1980) and are not suitable for measuring changes in the toughness of growing leaves in the field.

We describe an inexpensive, portable penetrometer which can be easily calibrated, and tongs for holding leaves while the penetrometer is operated. Our instrument does not require destructive sampling and can be used to monitor the progressive changes in toughness of leaves whilst they attached to the growing plant.

The portable penetrometer and tongs were devised to relate toughness of leaves on growing plants of the vine, *Stephania japonica* (Thunberg) Miers (Menispermaceae), to feeding by larvae of the fruit piercing moths, *Othreis fullonia* (Clerck) and *Eudocima salaminia* (Cramer) (Noctuidae). The penetrometer (Fig. 1) consisted of a dial gram gauge, with removable probes. The probes were made from stainless steel pins or rods with the apex ground flat, each 12 mm long, soldered at right angles onto a modified 3 mm electrical spade receptacle. Probes were slid over the flat feeler tip of the gauge and easily changed if different probe diameters were required for testing leaves of varying toughness. The gauge (Chatillon AG 50*) used for experiments with *S. japonica* was calibrated 0–50 g but gauges with 150, 300 and 500 g capacities are available for use on plants with greater leaf toughness. A probe measuring 400 μm in thickness was used for *S. japonica*. The tongs (Fig. 2) were constructed from 2 rectangular polyacrylamide plates, 160 × 33 ×

* John Chatillon and Sons, Inc., New York.

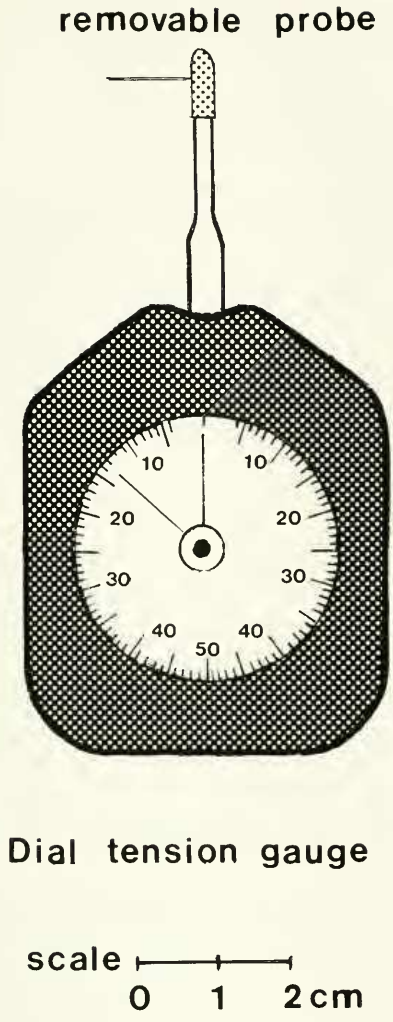

Fig. 1. Penetrometer.

5 mm, with tapered apices, drilled (2 mm in upper, 2.5 mm in lower plate) to accommodate the penetrometer probe. A hinge mounted between the plates 55 mm from the base allowed the tongs to be used in one hand to hold each leaf tested, while the penetrometer was operated in the other hand.

The penetrometer was calibrated by clamping it in a boss head clamp, pivoted on a retort stand so that the probe rested under pressure on an open pan of an electronic balance. Weights registered on the tension gauge were corrected for error by comparing readings with those on the electronic balance. Different pressures to cover the range of gauge readings were obtained by adding weights to the clamp arm.

When used on leaves of *S. japonica*, penetrometer readings had coefficients of variation of generally less than 5%. Readings showed that veins were tougher than areas between veins and that toughness decreased as leaves lost turgor after removal from the plants (Table 1). Hairs, glands, lesions and foreign bodies (such as scale insects) were avoided when taking measurements. Leaf tearing and compression were minimized by using a small diameter probe which also increased the sensitivity of gauge readings, when compared with readings using larger diameter probes.

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Table 1. Penetrometer readings* for leaves of *Stephania japonica*.

Leaf Stage	Upper Surface	Lower Surface	Primary Veins	Time after Picking		
				15 min	30 min	60 min
Expanding	14.2 (0.20)	16.4 (0.52)	24.6 (1.53)	13.4 (0.25)	13.0 (0.32)	13.0 (0.00)
Fully expanded	23.4 (0.94)	21.6 (0.52)	35.2 (2.09)	21.4 (0.61)	18.8 (0.75)	18.2 (0.50)
Presenescing	26.2 (0.81)	28.0 (1.33)	49.4 (0.41)	25.4 (0.51)	23.2 (0.59)	20.6 (0.69)

* Means in grams (±SE), n = 5, at 26°C, 75% RH, probe thickness 400 μm.

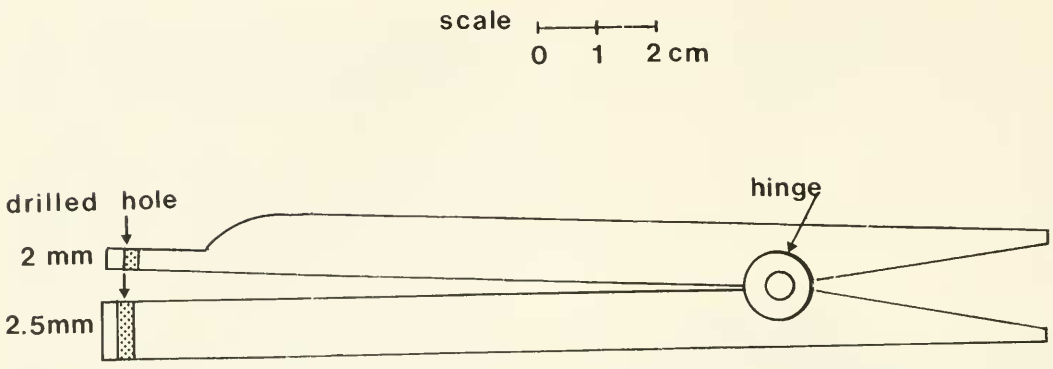

Fig. 2. Tongs.

probes. Mrs. Tini Schotz and Ms. Rose Broe helped with development of the techniques.

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